

1    Improved Valve

2

3    The present invention relates to valves typically used on  
4    downhole tools in oil and gas wells and in particular,  
5    though not exclusively, to a water injection valve.

6

7    In secondary recovery of oil and gas wells it is possible  
8    to use the technique of water flooding for enhanced oil  
9    recovery. This technique relies on injecting water into  
10   the reservoir and is normally undertaken using one or  
11   more water injection wells. Such valves are typically  
12   made up to a wireline lock or retrievable packer and run  
13   to depth. A suitable valve design comprises a body  
14   including a seat against which a poppet or other closing  
15   surface of the valve can rest. The poppet is biased  
16   towards the seat(s) to hold the valve in a closed  
17   position. Water passed down the tubing string of a well  
18   bore will arrive at the poppet, and the water pressure  
19   will work against the loading of the spring and force the  
20   poppet away from the seat. The water is then directed  
21   through ports in the poppet, whereupon it takes a  
22   convoluted path to return to a central path through the  
23   valve and exit at its base.

1 Such valves have a number of disadvantages. Typically  
2 these valves have a spring which applies a load to the  
3 poppet to keep the valve closed. Thus when water flows  
4 an initial pressure will open the valve but there is a  
5 tendency for the valve to close again as the pressure  
6 drops when the fluid is flowing through the valve.

7

8 A further disadvantage of these valves is in the  
9 arrangement of the ports through which the water flows  
10 when the valve is open. By the nature of the design,  
11 these ports are typically small in diameter and as such  
12 they increase the pressure drop through the valve. The  
13 convoluted narrow path also causes erosional problems  
14 through the valve and increases the potential debris  
15 build up in the valve which can cause the valve to fail.

16

17 Some water injection valves are designed as high lift  
18 valves. Such valves are designed so that the poppet  
19 moves easily to the full open position with the minimum  
20 water injection flow rate. Unfortunately such a high  
21 lift design results in a low load spring design producing  
22 low resultant closing forces on the poppet mechanism.  
23 This can lead to problems with debris ingress between the  
24 poppet and seat preventing a seal.

25

26 It is an object of at least one embodiment of the present  
27 invention to provide a valve which overcomes at least  
28 some of the disadvantages of prior art valves.

29

30 It is a further object of at least one embodiment of the  
31 present invention to provide a water injection valve  
32 having a high bypass flow area.

33

1 A yet further object of at least one embodiment of the  
2 present invention is to provide a water injection valve  
3 which is a high lift valve.

4

5 According to a first aspect of the present invention  
6 there is provided a valve for use in a downhole tool, the  
7 valve comprising a substantially tubular body including a  
8 first end for connection to a wireline lock or packer,  
9 the first end having a first inlet communicating with the  
10 string providing a flow path of a first cross-sectional  
11 area; one or more ports located on the body, the ports  
12 providing a flow path of a combined cross-sectional area  
13 greater than the first cross-sectional area; a sealing  
14 assembly comprising a seal cap moveable in relation to  
15 the body to open and close the ports; wherein fluid flow  
16 through the inlet moves the seal cap to open the valve  
17 and create an unimpeded flow path between the inlet and  
18 the ports with negligible pressure drop.

19

20 By creating a direct flow path from the inlet to the  
21 outside of the valve through the ports, which is  
22 unimpeded, that is the cross-sectional area of the flow  
23 path is not reduced, the problems associated with a  
24 pressure drop through the valve are alleviated.

25

26 Preferably the ports are arranged circumferentially on  
27 the tubular body. More preferably the cross-sectional  
28 area of the ports is greater than half the total surface  
29 area of the tubular body. In a preferred embodiment  
30 there are two substantially rectangular ports located on  
31 the tubular body. The ports are arranged such that they  
32 take up a substantial portion of the tubular body to  
33 provide for maximum flow through of fluid when the valve

1 is open. In the preferred embodiment portions of the  
2 tubular body between the ports provide longitudinally  
3 arranged rails.

4

5 Preferably the sealing assembly includes a first sealing  
6 surface and the tubular body includes a second sealing  
7 surface, the surfaces contacting to close the valve.

8

9 Preferably the seal cap is a poppet and the first sealing  
10 surface is an outer surface of the poppet located at an  
11 end of the sealing assembly. Preferably the second  
12 sealing surface is a seat located circumferentially on an  
13 inner surface of the tubular body. More preferably the  
14 sealing assembly includes biasing means to bias the  
15 poppet and the first sealing surface towards the second  
16 sealing surface.

17

18 Advantageously the biasing means is a spring located  
19 centrally within an enclosed bore of the sealing  
20 assembly. Preferably a first end of the spring locates at  
21 a base of the sealing assembly and an opposing end of the  
22 spring locates at a base of the poppet.

23

24 Preferably the outer surface of the poppet engages with  
25 the rails to maintain linear movement of the poppet  
26 within the tubular body.

27

28 Preferable the valve includes pressure release means to  
29 open the valve at a predetermined fluid pressure.

30 Preferably the pressure release means comprises shearing  
31 means which prevents movement of the poppet on the  
32 sealing assembly. Preferably also the second sealing  
33 surface is located on a floating component. In this way

1 seal is maintained between the surfaces until the  
2 shearing means is sheared. Advantageously the shearing  
3 means is a shear ring.

4

5 Optionally a load adjuster is located between the biasing  
6 means and the first surface to vary the load applied by  
7 the first surface upon the second surface. In a typical  
8 valve, as the first surface approaches the second surface  
9 to move the valve to the closed position, the load from  
10 the biasing means is at its lowest and the potential for  
11 debris build-up between the surfaces is at its highest.  
12 By incorporating a load adjuster, the load can be  
13 increased as the valve is closed, to pull the valve to  
14 the fully closed position. This increases the surface to  
15 surface contact load and resulting sealing performance of  
16 the valve, particularly where the valve is used as a high  
17 lift valve.

18

19 Preferably the load adjuster comprises a sprung collet.  
20 The sprung collet may comprise an engaging portion having  
21 sprung cantilevers extending therefrom. The engaging  
22 portion may be considered as a dog. Preferably the collet  
23 is arranged in parallel to a central longitudinal axis of  
24 the valve.

25

26 Preferably the load adjuster further includes at least  
27 one roller. Preferably at least one roller is mounted on  
28 the engaging portion or dog.

29

30 Preferably the roller is located against a running  
31 surface of the valve wherein the running surface is  
32 substantially parallel to the central axis. More  
33 preferably the running surface comprises three sloping

1 sections, a first sloping section being at a first angle  
2 to the running surface, a third sloping surface being at  
3 a second angle to the running surface and an apex of the  
4 first sloping surface being connected to the base of the  
5 third surface to provide the second sloping surface.

6

7 In an embodiment of the present invention the first and  
8 third sloping surfaces are angled at approximately ninety  
9 degrees to the running surface. In an alternative  
10 embodiment of the present invention the first and third  
11 sloping surfaces are at a steep angle to the running  
12 surface.

13

14 More preferably the load adjuster is arranged on an  
15 inner surface of the poppet and the running surface is  
16 arranged on an outer surface of the second tubular body.  
17 In this way biasing of the spring causes movement of the  
18 load adjuster along the outer surface of the second  
19 tubular body. In an embodiment, the sprung collet  
20 ensures that the roller is located against a sloping  
21 surface of the running surface when the tool is  
22 assembled.

23

24 Preferably the valve is an injection valve. The valve may  
25 be a water or gas injection valve. Alternatively the  
26 valve is a check valve as would be used in a downhole  
27 safety device.

28

29 According to a second aspect of the present invention  
30 there is provided a method of injecting fluid into a well  
31 bore, the method comprising the steps:

32

- 1       (a) locating an injection valve on an anchoring  
2              device at an end of a work string;
- 3       (b) running the string to a required depth;
- 4       (c) sealing the string to a wall of the well bore  
5              using the anchoring device;
- 6       (d) passing fluid at a first pressure through the  
7              work string; and
- 8       (e) using the fluid to open the valve and thereby  
9              inject fluid through an unimpeded path through  
10             the valve into the well bore while maintaining  
11             fluid pressure at the first pressure.

12  
13 Preferably the injection valve is according to the first  
14 aspect. The method may include the step of trapping  
15 pressure below the valve. This method makes the well  
16 safe on closure of the valve or if a sudden pressure  
17 increase is experienced below the valve.

18  
19 More preferably the injection valve incorporates the  
20 pressure release means and the method further includes  
21 the step of performing one or more pressure tests above  
22 the valve.

23  
24 While the terms 'up', 'down', 'top' and 'bottom' are used  
25 within the specification, they should be considered as no  
26 more than relative, as the valve of the present invention  
27 may be used in any orientation.

28  
29 Embodiments of the invention will now be described, by  
30 way of example only, with reference to the accompanying  
31 figures in which:

1       Figure 1 is a part cut-away cross-sectional view  
2       through a valve according to an embodiment of the  
3       present invention, shown in a (a) open and (b)  
4       closed configuration;

5  
6       Figures 2 illustrate a schematic view of the  
7       arrangement of the flow housing on the valve of  
8       Figure 1 wherein Figure 2(a), is rotated by ninety  
9       degrees with respect to Figure 2(b);

10  
11      Figure 3 is a cross-sectional view of a valve  
12      according to a further embodiment, wherein the left  
13      hand side of the figure illustrates the valve in the  
14      open configuration and the right hand side  
15      illustrates the valve in the closed configuration;

16  
17      Figures 4(a) and (b) are schematic illustrations of  
18      the position of the poppet seat and poppet when the  
19      valve of Figure 3 is moved to the closed position;  
20      and

21  
22      Figure 5 is a plot of valve closing characteristics  
23      comparing the spring load on a traditional injection  
24      valve against that of the injection valve of Figure  
25      3.

26  
27      Referring initially to Figure 1 of the drawings there is  
28      illustrated a valve, generally indicated by reference  
29      numeral 10, according to a first embodiment of the  
30      present invention. Figure 1(a) is the valve 10 in an  
31      open configuration, while Figure 1(b) is the valve 10 in  
32      a closed configuration. To those skilled in the art,  
33      valve 10 is recognisable as a water injection valve but

1 could equally be adapted to a check valve or other  
2 arrangement as would be found on a downhole tool for  
3 controlling fluid flow.

4

5 Valve 10 comprises a top sub 12 including a box section  
6 14 for connecting the valve 10 to an anchoring device  
7 i.e. a lock or packer. Typically the valve is made up to  
8 an wireline lock or retrievable bridge plug and run to  
9 depth, usually in the packer tail pipe. Top sub 12  
10 contains a bore 106. Bore 106 is the inlet to the valve  
11 10 so that fluid passed down the work string can input  
12 the valve. Bore 106 has a circular cross-section and at  
13 its narrowest diameter provides a flow path cross-  
14 sectional area at the inlet.

15

16 Threaded to the top sub 12 is a flow housing 18 held in  
17 place by set screws 16. The design of flow housing 18 is  
18 advantageous to the operation of the injection valve and  
19 will be described hereinafter with reference to Figure 2.  
20 The housing 18 is primarily a tubular body providing an  
21 outer surface 20 to the valve 10. At a lower end 22 of  
22 the housing 18 is attached a bottom sub or end cap 24.  
23 End cap 24 is threaded to the housing 18 and prevented  
24 from detachment by means of set screws 26.

25

26 End cap 24 includes a bore 32 into which is located a  
27 inner tube 34. Inner tube 34 provides a tubular body  
28 having an inner cylindrical surface 36 and an outer  
29 surface 38. Mounted within the inner cylindrical surface  
30 36 and located around an inner tubular centraliser 39 a  
31 spring 42. Spring 42 extends beyond the upper end 46 of  
32 the inner tube 34 and the upper end 41 of the centraliser  
33 39.

1 Centraliser 39 abuts the end of the bore 32 in the bottom  
2 sub 24. Centraliser 39 abuts the end cap 24. For  
3 assembly, a snap ring 43 is located between the  
4 centraliser 39 and the tube 34. Centraliser 39 also  
5 includes an axial bore 45 which aligns with an exit bore  
6 47 through the end cap 24. These bores 45,47 provide  
7 fluid access in a chamber 49 in which the spring 42 is  
8 located.

9

10 The upper end of spring 42 is bounded by an upper spring  
11 housing 51. Housing 51 comprises a cylindrical sleeve 55  
12 having a lip 53 on the outer surface at a lower end  
13 thereof. The sleeve 55 is threaded to a cap 57 at the  
14 upper end of the spring 42. Inner tube 34 includes a lip  
15 59 on an inner surface at the top 46. Lips 53,59 engage  
16 to prevent longitudinal movement to separate the housing  
17 51 from the tube 34.

18

19 Located on the cap 57 is a poppet 84 providing a rounded  
20 nose cone 104 which locates in the bore 106 on the top  
21 sub 12. Poppet 84 further provides a frusto-conical  
22 surface 108 which includes a ledge 110 which provides a  
23 sealing surface 111 to seal against a poppet seat 112  
24 located on the flow housing 18. Poppet seat 112 provides  
25 a further sealing surface 113 which when it meets the  
26 surface 112 seals the bore 106 to prevent fluid flow  
27 which enters the bore 106 from exiting the valve 10.  
28 This configuration can therefore be considered as a  
29 closed configuration of the valve 10. Appropriate O-  
30 rings 114a and 114b are located between the poppet seat  
31 112 and the inner surface 116 of the flow housing 18, and  
32 between the top sub 12 and the flow housing 18,

1 respectively. This prevents the ingress of fluid through  
2 the valve 10.

3

4 The ledge 110 and thus the poppet 84 is held against the  
5 poppet seat 112 by the spring 42 and the surfaces 111,113  
6 seal together. This closed position is shown on the  
7 Figure 1(b) wherein the poppet 84 is seated on the poppet  
8 seat 112 and there is no flow through the valve.

9

10 Threaded and held by set screws 86 to a recess 88 on an  
11 outer surface 90 of the poppet 84, is a poppet skirt 68.  
12 The skirt 68 provides a streamlined profile running back  
13 to the inner tube 34. Skirt 68 is sized to fit around  
14 the inner tube 34 and a wiper ring 69 is located  
15 therebetween. The ring 69 allows the poppet 84 to move  
16 longitudinally relative to the tube 34 and housing 18.  
17 Attached to a lower end 71 of the skirt 68 is a shear  
18 ring housing 73 which abuts a shear ring 75 located on  
19 the outer surface 38 of the tube 34.

20

21 In this way, the poppet 84 is held in a sealed position  
22 until sufficient force is applied to shear the shear ring  
23 75. On shearing the parts of the ring 75 are held within  
24 the shear ring housing 73. This means that the parts  
25 cannot come away from the valve and cause the valve to  
26 malfunction or have part of the shear ring 75 left  
27 downhole to cause damage to other equipment.

28

29 By including the shear ring 75, the poppet 84 can hold  
30 pressure from above and below the valve in the closed  
31 configuration. To allow the poppet 84 to hold pressure  
32 from above the poppet seat 112 has 'float' built in i.e.  
33 the top sub 12 and the housing 18 provide a recess at the

1 seat 112 longer than the length of the seat 112 so that  
2 it can travel longitudinally between defined limits.  
3 This float allows the poppet 84 and the seat 112 to move  
4 down together as fluid is applied from above. The float  
5 also addresses any tolerance issues and gives enough  
6 stroke to ensure the shear ring 75 is sheared properly  
7 before the poppet seat 112 bottoms out and the poppet 84  
8 comes off seat allowing fluid to pass through the passage  
9 120.

10

11 Selection of the pressure rating of the shear ring,  
12 provides a value at which pressure can be tested above  
13 the valve in the closed configuration. Any number of  
14 tests can be performed as long as the overall pressure in  
15 the bore 106 is not allowed to exceed the rating of the  
16 shear ring 75. The pressure is then exceeded to shear  
17 the ring 75 and allow fluid to be injected through the  
18 valve 10.

19

20 On opening, fluid pressure acts on the poppet 84 and it  
21 is forced downwards against the spring 42. While pressure  
22 is maintained fluid flows freely and directly from the  
23 bore 106 to the ports 132 on the housing 18. Due to the  
24 cross-sectional area of the flow path 120 through the  
25 ports 132, greatly exceeding the input flow path cross-  
26 sectional area at the bore 106, there is negligible  
27 pressure drop as the valve 10 is opened. The pressure  
28 will thus remain substantially constant through the valve  
29 as it is opened and in use. The opened configuration is  
30 shown in Figure 1(a).

31

32 The profile of the nose 104 together with the skirt 68  
33 provides a streamlined flow passage 120 to maximise fluid

1 flow through the valve in the open position. This is  
2 further enhanced by the design of the flow housing 18  
3 located around the inner tube 34. This is seen with the  
4 aid of Figure 2.

5

6 Figure 2(a) provides a side view of the housing 18, while  
7 Figure 2(b) shows the same housing rotated by 90 degrees.  
8 Flow housing 18 comprises a tubular body 130 which has a  
9 diameter less than or equal to the diameter of the top  
10 sub 12. Oppositely arranged on the body 130 are two  
11 slots or ports 132. Ports 132 are arranged  
12 longitudinally and cover a substantial portion of the  
13 valve 10, beginning at the top sub 12 and ending near the  
14 end cap 24. Ports 132 are substantially rectangular in  
15 cross-section having a rounded portion 134 toward the end  
16 cap 24. The ports 134 may be of any chosen dimensions  
17 but must provide a cross-sectional area that is greater  
18 than the cross-sectional area of the bore 106. Preferably  
19 the cross-sectional area of the ports is approximately an  
20 order of magnitude greater than the cross-sectional area  
21 of the bore 106. The shape in this embodiment is as a  
22 consequence of milling through a cylinder formed on a  
23 slope. Together the ports 132 remove a suostantial  
24 portion of the body 130 to provide maximum flow of fluid  
25 through the valve 10. Portions of the body 30 remaining  
26 to either side of the ports 132 provide rails 136 used to  
27 help guide the poppet 84 through the valve without  
28 impeding its path. Thus as can be seen from Figure 2(a)  
29 that the poppet 84 and poppet skirt 68 are substantially  
30 exposed within the body 130.

31

32 This cut-away to flow housing 18 results in the valve 10  
33 having a high bypass flow area which minimises the

1 pressure drop and erosion problems through the valve 10.  
2 This additionally reduces the debris build up potential  
3 as there are less surfaces, ledges or other surface areas  
4 which the flow path impinges on where debris could  
5 collect.

6

7 In an alternative embodiment, the areas of the valve 10  
8 which are exposed to the injection flow rates such as the  
9 nose cone 104 and surfaces of the flow housing 18, may be  
10 coated with a tungsten carbide based coating. The  
11 coating is directed to areas where the direction of flow  
12 changes in particular. The coating is included to help  
13 protect the valve sealing surfaces from the effects of  
14 erosional flow particularly when large amounts of debris  
15 are anticipated. Such coatings are known to those  
16 skilled in the art of downhole ball valve technology.

17

18 In an alternative embodiment of the present invention,  
19 the poppet seat 112 is made reversible which will help  
20 reduce valve redress costs. In a yet further embodiment,  
21 the poppet seat is provided as a soft seal. This  
22 embodiment is thus particularly suitable for applications  
23 where water and gas are injected alternately through the  
24 valve and the soft seal improves the gas sealing  
25 characteristics of the valve.

26

27 Reference is now made to Figure 3 of the drawings which  
28 illustrates a valve, generally indicated by reference  
29 numeral 100, according to a second embodiment of the  
30 present invention. Like parts to those of the valve 10  
31 have been given the same reference numeral. Figure 3  
32 illustrates the valve 100 in closed (right hand side) and  
33 open (left hand side) configurations. To those skilled in

1 the art, valve 100 is recognisable as a water injection  
2 valve but could equally be adapted to a check valve or  
3 other arrangement as would be found on a downhole tool  
4 for controlling fluid flow.

5

6 Valve 100 comprises a top sub 12 including a box section  
7 14 for connecting the valve 100 to an anchoring device  
8 i.e. a lock or bridge plug. Typically the valve is made  
9 up to an wireline lock or retrievable bridge plug and run  
10 to depth, usually in the packer tail pipe. Threaded to  
11 the top sub 12 is a flow housing 18. The housing 18 is  
12 primarily a tubular body providing an outer surface 20 to  
13 the valve 100. At a lower end 22 of the housing 18 is  
14 attached a bottom sub or end cap 24. End cap 24 is  
15 threaded to the housing 18 and prevented from detachment  
16 by means of set screws 26. There is also located an  
17 adjustment nut 28 and an adjacent lock nut 30 so that the  
18 relative positioning between end cap 24 and the housing  
19 18 can be set.

20

21 End cap 24 includes a bore 32 into which is located a  
22 inner tube 34. Inner tube 34 provides a tubular body  
23 having an inner cylindrical surface 36 and an outer  
24 surface 38. Mounted within the inner cylindrical surface  
25 and abutting a base 40 of the bore 32 is a spring 42.  
26 Spring 42 extends beyond the upper end 46 of the inner  
27 tube 34.

28

29 From the end 46, the outer surface 38 provides a  
30 substantially longitudinal portion 48, running in  
31 parallel to the spring 42 which is aligned on a central  
32 axis 50 of the valve 100. Portion 48 meets a face 52  
33 which rises outwardly from the surface 38 at an angle of

1 approximately seventy-five degrees. This provides an  
2 acute ramp on the outer surface 38. Thereafter the outer  
3 surface provides a gentle ramp 56 toward a second face 54  
4 which provides a second acute face as that of the face  
5 52. Between each face 52,54 the outer surface 38 the  
6 gentle ramp 56 extends from the apex 60 of the face 52 to  
7 the base 62 of the face 54. This ramp 56 is directed  
8 toward the central axis 50 as it travels toward the end  
9 cap 24.

10

11 Located below the face 54 are the end portions of a first  
12 collet spring 66 and a poppet skirt 68. The collet spring  
13 66 and the poppet skirt 68 are threaded together and  
14 locked by set screws 64. The collet spring 66 and the  
15 poppet skirt 68 can slide on the outer surface 38 of the  
16 inner tube 34.

17

18 Collet spring 66 extends toward the upper end 70 of the  
19 valve 100 providing a cantilevered release spring  
20 terminating at a dog 72. Dog 72 is a typical dog  
21 providing inner 74 and outer 76 raised portions. Although  
22 only one dog 72 is illustrated, it will be appreciated  
23 that any number can be arranged around the inner tube 34.  
24 Dog 72 is connected to a further collet spring 78 whose  
25 end 80 extends toward the upper end 70 of the valve 100.  
26 The collection of collet spring 78, dog 72 and collet  
27 spring 66 'fingers' provide a collet generally indicated  
28 by reference numeral 109.

29

30 Typically, the collet 109 is formed by turning a profile  
31 onto a cylinder and then milling parallel slots through  
32 the cylinder axially within its length. The amount of  
33 parallel slots arranged around the circumference equals

1 the number of fingers (collet spring 78, dog 72 and  
2 collet spring 66). The fingers act like a beam supported  
3 at each end. End 80 of collet 109 is cylindrical and  
4 supported within a corresponding cylindrical inner  
5 surface 82 of a poppet 84.

6

7 The poppet skirt 68 is threaded and held by set screws 86  
8 to a recess 88 on an outer surface 90 of the poppet 84.  
9 Located above the collet spring 78 on the poppet 84 is a  
10 spring washer 92. Spring washer 92 includes an inner lip  
11 94 arranged to face the end cap 24 and retain a top end  
12 96 of the spring 42.

13

14 Mounted upon the dog 72 is a wheel 102 arranged so that  
15 it can ride upon the outer surface 38 of the inner tube  
16 34. Indeed the wheel 102 may locate on the face 52, run  
17 along the ramp 56 towards face 54 as described  
18 hereinafter with reference to Figure 4. An end 69 of the  
19 skirt 68 meets an inner surface 71 of the flow housing  
20 18. Spring 42 is thus contained between a base 40 of the  
21 end cap 24 and the lip 94 of the spring washer 92 and its  
22 movement is controlled by the movement of the collet 109  
23 in relation to the outer surface 38 of the inner tube 34.

24

25 The poppet 84 provides a rounded nose cone 104 which  
26 locates in a bore 106 on the top sub 12. Poppet 84  
27 further provides a frusto-conical surface 108 which  
28 includes a ledge 110 which provides a sealing surface 111  
29 to seal against a poppet seat 112 located on the flow  
30 housing 18. Poppet seat 112 provides a further sealing  
31 surface 113 which when it meets the surface 112 seals the  
32 bore 106 to prevent fluid flow which enters the bore 106  
33 from exiting the valve 100. This configuration can

1 therefore be considered as a closed configuration of the  
2 valve 100. Appropriate O-rings 114a and 114b are located  
3 between the poppet seat 112 and the inner surface 116 of  
4 the flow housing 18, and between the top sub 12 and the  
5 flow housing 18, respectively. This prevents the ingress  
6 of fluid through the valve 100.

7

8 The ledge 110 and thus the poppet 84 is held against the  
9 poppet seat 112 initially by the spring 42 and further by  
10 the collet 109 when the dog 72 is located at the face 52  
11 and the wheel 102 abuts the face 52.

12

13 This closed position is further illustrated with the aid  
14 of Figure 4. In Figure 4(a) the wheel 102 is located at  
15 the apex 60 of the face 52. At this position the poppet  
16 seat 112 and the poppet 84 are close to touching. This  
17 is the location that a typical water injection valve of  
18 the prior art would find its spring load at its lowest  
19 and the potential for debris problems are at their  
20 highest. At this position the collet 109 and in  
21 particular the collet springs 66, 78 take over from the  
22 spring 42 and drive the poppet 84 to the fully seated  
23 position against the poppet seat 112. As this occurs the  
24 wheel 102 runs down the acute face 52 and locates there  
25 against. The poppet seat 112 is now located within the  
26 ledge 110 of the poppet 84 and the surfaces 111,113 seal  
27 together.

28

29 In this position the collet 109 preloads the poppet 84  
30 against the poppet seat 112. Thus the collet 109 has  
31 pulled the valve to the fully closed position. This  
32 increases poppet 84 to seat 112 contact load and enhances  
33 the resultant sealing performance of the valve.

1 This closed position is shown on the right hand side of  
2 Figure 3 wherein the poppet 84 is seated on the poppet  
3 seat 112 and there is no flow through the valve. In  
4 order to initiate flow through the valve, water or other  
5 fluid is passed through the bore 106. Water causes a  
6 pressure on the nose 104 of the poppet 84 and pushes it  
7 towards the end cap 24.

8

9 Opening of the valve occurs as poppet 84 moves downwards  
10 as shown on the left hand side of Figure 3. As it moves  
11 downwards a flow passage 120 is uncovered through the  
12 housing 18. On depression of the poppet 84, the wheel  
13 102 is caused to ride up the face 52. The seal between  
14 the surfaces 111,113 is broken. Due to the close fit  
15 between the ledge 110 and the seat 112, the load due to  
16 the, now leaking, pressure will be sufficient to allow  
17 the wheel 102 to reach the apex 60. Once over the apex 60  
18 the wheel runs rapidly down the ramp 56 towards the face  
19 54. An end 69 of the poppet skirt 68 meets an inner  
20 surface 71 of the flow housing 18. Once the dog 72 has  
21 been pushed out of the groove provided by face 52 on  
22 valve opening, the drag friction from the collet 109 has  
23 been minimised so this does not detract from the spring  
24 42 return load.

25

26 Thus when the valve is opened, the valve operates as a  
27 high lift valve. This means the poppet 84 moves easily to  
28 the full open position with minimal water injection flow  
29 rate. Use of the high lift design minimises potential  
30 for debris build up above the valve at the location of  
31 the seat 112 in the top sub 12.

32

1 Returning to Figure 3, there is illustrated a poppet  
2 skirt 68. Poppet skirt 68 is threaded to the recess 88  
3 on the poppet 84. The skirt 68 provides a streamlined  
4 profile running back to the threads 64 which attach it to  
5 the collet 109. Such a profile of the nose 104 together  
6 with the skirt 68 provides a streamlined flow passage 120  
7 to maximise fluid flow through the valve in the open  
8 position. This is further enhanced by the design of the  
9 flow housing 18 located around the inner tube 34. This  
10 housing 18 is illustrated in Figure 2 and is described  
11 hereinbefore with reference to the Figure. In this way  
12 the relationship between the cross-sectional area of the  
13 flow path at the bore 106 is smaller than the cross-  
14 sectional area through the ports 132 as they are opened.  
15

16 This cut-away to flow housing 18 results in the valve 100  
17 having a high bypass flow area which negligible pressure  
18 drop and minimises erosion problems through the valve  
19 100. This additionally reduces the debris build up  
20 potential.

21  
22 It is also noted that the collet 109 is located within a  
23 "dead area" of the valve 100 where fluid flow is not  
24 experienced and this minimises the effects to the flow  
25 and keeps it away from any debris passing through the  
26 valve 100.

27  
28 In use, valve 100 is run into a well bore typically made  
29 up to a wireline lock or a retrievable bridge plug, and  
30 run to depth in the closed configuration. Once in  
31 position, fluid to be injected through the valve 100 is  
32 introduced to the bore 1006 at a suitable pressure.  
33 Fluid pressure exerted on the nose 104 of the poppet 84

1 acts against the spring 42. The poppet 84 is thus moved  
2 from sealing engagement with poppet seat 112 in a  
3 downwards relative direction. On opening, the wheel 102  
4 of the collet 100 rides up the face 52 of the surface 38  
5 and then runs down the ramp 56 towards face 54. An end  
6 69 of the skirt 68 meets an inner surface 71 of the flow  
7 housing 18. The valve is now open. Flow rate through the  
8 valve is through bore 106 into flow ports 120 exiting  
9 through the ports 132 within the flow housing 18.

10  
11 When the valve is to be closed, water pressure is reduced  
12 in the bore 106. Load from the spring 42 acts against  
13 the poppet 84 to move it back toward the poppet seat 112.  
14 Movement is effected relatively easily as the wheel 102  
15 of the collet 109 moves up the ramp 56. When the wheel  
16 102 reaches the apex 60 of the face 52 the collet springs  
17 66, 78 take over from the spring 42 and drive the poppet  
18 84 into the seated position against the poppet seat 112.  
19 Surfaces 111 and 113 abut to form a seal. In the fully  
20 seated position collet 109 preloads the poppet 84 as the  
21 wheel 102 is now located against the face 52.

22  
23 Reference is now made to Figure 5 of the drawings which  
24 is a plot of valve position 122 between the open and  
25 closed configuration against spring load on the poppet  
26 84. Two graphs are provided. The first 126 shows a  
27 typical injection valve load characteristic for prior art  
28 injection valves. In this configuration it is seen that  
29 the load follows a straight line from a high spring load  
30 125 when the valve is fully open, down to a lower value  
31 123 when the valve is closed. This is a linear  
32 relationship. Line 128 illustrates the valve load  
33 characteristics of a valve according to at least one

1 embodiment of the present invention. The initial  
2 gradient is shallower than the prior art valve and may be  
3 considered to approximate to a near constant load. This  
4 is due to the weaker start required of the valve and the  
5 gradient doesn't increase since the valve is designed  
6 with a single large coiled spring. Line 128 follows this  
7 linear downward path until just before the valve is  
8 closed at position 130. As the valve is closed an  
9 additional load is generated by the collet springs 66, 78  
10 and as a result the graph rises sharply to a value 127  
11 which may be considerably larger than the value of the  
12 spring load of the traditional valve in the closed  
13 configuration.

14  
15 The principle advantage of the present invention is that  
16 it provides a valve having a high bypass flow area with a  
17 smooth flow path which minimises pressure drop and  
18 erosion problems through the valve while also reducing  
19 debris build-up potential in the valve. Production flow  
20 is thus optimised and is only restricted by the bore of  
21 the anchoring device.

22  
23 A further advantage of an embodiment of the present  
24 invention is that it provides an injection valve which by  
25 the inclusion of a shear ring provides a barrier to  
26 pressure from both above and below so that pressure  
27 testing can be performed.

28  
29 A further advantage of an embodiment of the present  
30 invention is that it provides a valve for a downhole tool  
31 in which the load upon the poppet can be maximised when  
32 the valve is closed and the poppet is seated against the  
33 poppet seat.

1 It will be appreciated by those skilled in the art that  
2 modifications may be made to the invention herein  
3 described without departing from the scope thereof.  
4 Additionally though a poppet is shown, any suitable  
5 arrangement of two sealing surfaces could be used. Yet  
6 further the size and number of ports in the flow housing  
7 may be changed to vary the flow rate through the valve,  
8 while maintaining the desired relationship between the  
9 cross-sectional areas. Additionally the skirt may be  
10 provided with downward facing ridges such that it  
11 provides a streamlined profile to water passage from  
12 above and ledges against which water from below can  
13 impact, to assist in returning the poppet to the closed  
14 position.